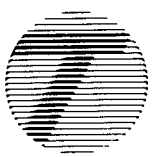
REPORT FHWA/NY/RR-88/143

Development of a Statewide Pavement Marking Policy

JAMES E. BRYDEN



RESEARCH REPORT 143

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DEVELOPMENT OF A STATEWIDE PAVEMENT-MARKING POLICY

James E. Bryden, Civil Engineer III (Physical Research)

Fourth Interim Report on Research Project 157-1
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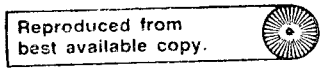
Research Report 143
July 1988



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16. Abstract

This report describes development of a statewide pavement-marking policy by the New York State Department of Transportation. An overview of the Department's marking program under the previous policy is presented, including program scope, material costs, and marking durability. Shortcomings of the former policy are reviewed, and considerations for the new policy are discussed. Several options are outlined and evaluated in terms of costs and program effectiveness. The Department has set a goal of providing effective year-round markings on all state-maintained highways. To accomplish this, durable marking materials will be applied by contract on all expressways and high-volume urban arterials. Highway Maintenance Division forces will mark other highways with an improved chlorinated-rubber traffic paint. Several improvements in the program will result in better marking performance and reduced unit costs. The net result is expected to be a substantial improvement in the pavement-marking program with only a nominal cost increase.

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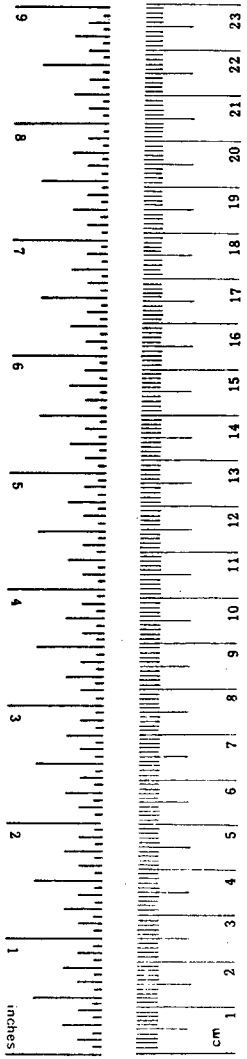
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

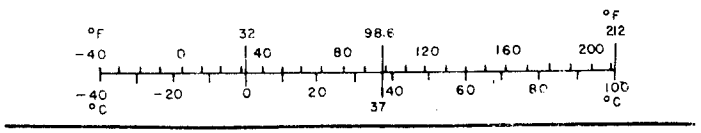
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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I. INTRODUCTION

Before the late 1970s, most pavement markings on state highways in New York State consisted of beaded traffic paint applied by Department maintenance personnel. Use of durable marking materials was limited to small quantities, generally for intersection markings and other special purposes on high-volume urban roadways. By the late 1970s, however, it had become increasingly apparent that traffic paint could not provide effective year-round markings in New York's severe climate. At the same time, experience with durable markings demonstrated their cost effectiveness in meeting the goal of year-round markings, especially on high-volume highways (1).

In 1979, the Department adopted its first formal pavement-marking policy (2), with the goal of providing adequate year-round markings. It called for including durable pavement markings on contract work. Thermoplastics were specified for asphalt pavement, based on favorable price and a good performance record. Preformed plastic tape was permitted on lighted highways where retroreflectivity was not critical, and where small quantities or special markings reduced the price differential compared to thermoplastic. Tapes were also allowed on concrete pavement, but only in limited quantities because of their high cost and little experience with them on tine-textured surfaces.

In 1983, this policy was revised (3) to reflect advances in marking technology. Thermoplastic continued to be the designated marking for most asphalt pavement, with two-component epoxy designated for concrete. Preformed plastic tape could be substituted where small quantities reduced price differentials, and for high-volume intersection work. On projects with both asphalt and concrete pavements, two-component epoxy was permitted on both.

Under this policy, durable markings were included on all capital contract work where pavement conditions were suitable. However, where unsuitable, as on pavements needing overlay, painted markings were applied by Maintenance forces. In addition to including durable markings in highway construction and reconstruction contracts, the Department made wider use of pavement-marking contracts to install durable materials on highways where painted markings could not provide good year-round delineation. Several contracts were let each year to install several hundred miles of markings at locations around the state. These included interstate highways, high-volume roadways, and remote highways where repainting caused scheduling difficulties.

The Department remains committed to providing effective year-round delineation on all state highways, and to accomplishing this in the most cost-effective manner. To meet this objective, the Department has continued careful monitoring of performance of each marking material it uses, as well as promising new materials, and reviewing the effectiveness of the various programs to install

and maintain pavement markings. Those efforts have been described in numerous research reports (4,5,6,7,8,9,10,11). By 1986, five specific developments caused Department management to re-examine the 1983 pavement-marking policy to determine where improvements could be made.

1. Experience with chlorinated-rubber traffic paint in accelerated wear tests and two small pilot installations confirmed that this material provided much better durability than the Department's standard modified-alkyd paint. Plans were made to convert one of the Department's regions to this material in 1987, with others to follow in subsequent years. Although more expensive, this material appeared capable of greatly improving marking effectiveness, as well as the efficiency of the Highway Maintenance Division's striping program.

2. Because durable markings were included in nearly all capital contracts, quantities were very small on some projects. This often resulted in bid prices considerably higher than on larger contracts.

3. Although most durable markings continued to perform well, markings on small contracts or those with scattered locations sometimes exhibited premature failure, or were restriped with traffic paint while still serviceable.

4. Because paving on capital contracts is often completed near the end of the construction season, numerous scheduling conflicts were encountered in completing durable marking installations on many contracts late in the fall.

5. Numerous discontinuities in pavement markings along highway corridors throughout the state resulted from the practice of installing durable markings primarily in conjunction with capital construction projects.

In 1986, the Technical Services Division was assigned the task of re-examining the Department's pavement-marking policy and developing proposed changes to increase its cost effectiveness. This report presents the supporting information, data, and analyses that were compiled, as well as explaining the revised policy that was developed (12).

II. PROGRAM REVIEW AND MATERIAL PERFORMANCE

Although basic concepts for the revised policy had been evolving for some time, the first formal step in its development was compilation of data on pavement-marking performance and the scope of the statewide program under the previous policy, and projection of striping costs and performance under a revised policy. This information could then form the basis for development and assessment of various options for the new policy. This chapter presents and discusses the program and performance data compiled.

A. Program Overview

To improve cost effectiveness in the new program, it is necessary to characterize both scope and costs of the existing program. Highway inventory data were obtained from the Planning Division to define the scope of the highway network in various system categories. Selection of the actual categories is discussed in Chapter III. State highway mileages for selected categories were as follows:

System	Centerline Miles	Lane Miles
Interstate	916	4,397
Other Limited Access	1,440	5,894
Urban Arterial, 4-lane, AADT >10,000	575	2,298
Urban Arterial, 2-lane, AADT >5,000	1,193	2,386
Other	11,381	24,363
Totals	15,505	39,338

After completion of policy development, breakdowns were provided for each of the Department's regions (except New York City), and forwarded to regional offices for use in program planning. New York City was not covered by this policy because all maintenance on state highways within the city, including pavement markings, is completed under contract by city maintenance forces.

B. Contract Markings

Beginning in the early 1970s, the Department split its pavement-marking responsibility between Maintenance forces -- primarily traffic paint -- and capital contracts -- mostly durable markings. The capital durables program has

been steadily increasing, and when development of the new policy began, annual summaries were available through 1985. Because 1985 represents the most recent and largest annual capital program, data from that year were used to make decisions regarding the new program. Table 1 summarizes costs and quantities for all pavement markings let to contract in 1985. Installation of some markings was completed that year, while others were scheduled for subsequent years on multi-year contracts. These markings were included in both construction-resurfacing contracts and in a small number of separate pavement-marking contracts. Also included in Table 1 are summaries for Maintenance-applied markings, discussed in subsequent sections.

Two concerns prompting this policy review were the perceived relationship between project quantity and unit price for durable markings, and the problems associated with scheduling pavement marking on projects with late-season completions. Thus contract experience was reviewed in these contexts. Table 2 summarizes distribution of unit costs and contract quantities for epoxy and thermoplastic longitudinal markings on 1985 contracts. Weighted average bid prices were $0.29/ft and $0.34/ft, respectively. The ranges of prices, however, were very wide for both materials, and bid prices on several contracts were considerably more than double the weighted averages. Examining the relationship between contract quantity and unit price revealed that most of the highest unit prices were for small quantities, and large contract quantities almost always resulted in comparatively low unit prices. This is shown in Table 3, which presents weighted average unit prices for various contract sizes. Contracts below 50,000 ft were markedly more expensive than larger contracts. Between 50,000 and 100,000 ft, unit prices tended to level off, and above 100,000 ft, prices were relatively stable. Although a small number of very large contracts had very favorable prices, the sample was too small to predict future prices on similar contracts.

Table 4 summarizes contracts including durable markings by region for both 1985 and 1986 -- with quantities expressed in miles of longitudinal lines. This table includes all contracts let in 1985 and 1986, contracts completed in autumn 1985, and projected completions for autumn 1986. Most contracts were less than 100,000 ft total quantity, and about half were scheduled for fall completion. This confirms the perceived problem with late-season completions.

C. Performance of Durable Pavement Markings

Research reports previously referenced provided information on service lives of durable pavement markings in New York State. However, current information on marking durability was desirable to determine the performance of epoxy and thermoplastic markings as currently employed in the Department's striping program.

To compile this information, a statewide marking survey was conducted in 1986. This survey examined 49 contracts including epoxy markings, and 100 with thermoplastic, all striped between 1981 and 1985. The epoxy projects represented all those including such markings over that period, but the thermoplastic projects were randomly selected from all those striped to provide a uniform statewide geographic distribution. Four locations were identified

Table 1. Summary of the 1985 pavement-marking program.

Program	Material	Quantity, miles	% of Total	Unit Cost, $/ft*	Cost, $M	% of Cost
LONGITUDINAL MARKINGS						
Maintenance	Modified-Alkyd	48,620	93.3	0.025	6.5	36.7
Capital	Thermoplastic	2,280	4.4	0.34	4.1	23.2
Capital	Epoxy	860	1.6	0.29	1.3	7.4
Capital	Preformed Tape	120	0.2	1.70	1.0	5.6
Capital	Modified-Alkyd	245	0.5	0.18	0.2	1.1
Capital	Pavement Preparation	530	--	0.20	0.6	3.4
Subtotal		52,125	100.0		13.7	
SPECIAL MARKINGS						
Maintenance	All	--	--	--	0.8	4.5
Capital	All	--	--	--	3.2	18.1
Total		52,125	100.0		17.7	100.0

*Contract prices based on weighted average bid prices.

Table 2. Epoxy and thermoplastic quantities and unit costs.

Unit Price Range, $/ft	Frequency		Quantity Range, lin ft	Frequency	
	Thermoplastic	Epoxy		Thermoplastic	Epoxy
0.00-0.10	0	0	0-20,000	83	29
0.10-0.20	1	2	20,000-40,000	30	9
0.20-0.30	62	8	40,000-60,000	19	5
0.30-0.40	45	10	60,000-80,000	15	2
0.40-0.50	49	10	80,000-100,000	18	0
0.50-0.60	21	5	100,000-120,000	13	1
0.60-0.70	6	3	120,000-140,000	7	0
0.70-0.80	5	1	140,000-160,000	5	3
0.80-0.90	2	5	160,000-180,000	1	0
0.90-1.00	10	8	180,000-200,000	3	2
1.00-1.10	0	1	200,000-220,000	2	1
1.10-1.20	0	0	220,000-240,000	3	1
Over 1.20	5	3	Over 240,000	7	3

Table 3. Durable marking unit prices related to contract quantity.

Epoxy		Thermoplastic	
Weighted Unit Prices, $/ft	Contract Quantity, gallons	Weighted Unit Prices, $/ft	Contract Quantity, gallons
0.735	<20,000	0.537	<20,000
0.264	>20,000	0.327	>20,000
0.563	<50,000	0.460	<50,000
0.240	>50,000	0.310	>50,000
0.526	<75,000	0.430	<75,000
0.231	>75,000	0.310	>75,000
0.526	<100,000	0.374	<100,000
0.231	>100,000	0.316	>100,000

Table 4. Summary of 1985 and 1986 contract lettings including thermoplastic and epoxy pavement markings.

Region	1985 Number of Contracts	1985 Contracts Under 100,000 ft Number	1985 Contracts Under 100,000 ft Mileage*	1986** Number of Contracts	1986** Contracts Under 100,00 ft Number	1986** Contracts Under 100,00 ft Mileage*
TOTAL ANNUAL CONTRACT LETTINGS						
1	26	18	89	22	19	99
2	14	8	32	14	14	80
3	23	14	104	10	8	50
4	22	18	131	18	13	79
5	38	37	129	26	20	88
6	22	21	172	12	11	64
7	11	8	83	15	11	93
8	35	27	133	23	17	99
9	18	11	41	17	7	47
10	27	24	105	22	21	103
Total	236	186	1019	179	141	802
ESTIMATED CONTRACT COMPLETIONS AFTER AUGUST 31						
1	14	13	97	12	14	104
2	9	6	28	9	11	51
3	11	6	68	5	3	34
4	13	8	54	11	6	40
5	15	13	68	10	7	37
6	17	15	169	9	8	90
7	7	4	34	10	6	51
8	13	7	31	9	4	18
9	9	6	37	9	4	25
10	8	8	45	7	7	39
Total	116	86	631	91	70	489

*Total stripe mileage.
**1986 status of contracts not available when this report was prepared. Fall projection based on ratio of 1986 to 1985 lettings.

on each project in the office in advance of field inspection to provide unbiased inspection sites. Thus, a total of 196 epoxy and 400 thermoplastic sites were selected. At all sites, each marking type -- edge lines, centerline, lane line, etc. -- was inspected individually. Because roadway configuration varied among sites, the number of samples varied from 1 to 4 at individual sites. In all, 496 epoxy and 812 thermoplastic samples were inspected. Three evaluation criteria were applied to each sample, with all inspections completed by two-person crews made up of engineers and/or technicians, all with extensive experience in rating pavement markings. Rating criteria were as follows:

1. Reflectivity

   For each sample, five retroreflectivity measurements were made over a 50-ft length of solid line, or one measurement each on five consecutive skip lines. Readings were made with a Michigan retroreflectometer described in earlier reports (4,5) and average quantitative measurements

for each sample were converted to a qualitative rating of excellent, good, fair, or poor.

2. Physical Condition

The percent of material remaining was estimated for the samples measured for retroreflectivity. Qualitative ratings were then assigned according to the following scale:

Excellent = More than 90 percent remaining,
Good = 71 to 90 percent remaining,
Fair = 51 to 70 percent remaining, and
Poor = 50 percent or less remaining.

3. Daytime Delineation

A subjective delineation rating was assigned to each site based on the overall condition of all markings as viewed from the inspection vehicle, using the following scale:

Good = Lines appeared essentially the same as new, with only minor imperfections visible,
Fair = Visually effective, but imperfections were readily apparent from a moving vehicle,
Poor = Extensive failure and areas of missing markings, discoloration, and imperfections were visible. The line still delineated the pavement, but was marginal in terms of effectiveness, and
Failed = Widespread failure, line no longer provided adequate delineation.

At the time of inspection, some marking samples had been painted over with traffic paint. Thus, each sample site was noted as not painted, partially painted, or completely painted, in addition to the three primary evaluation criteria. In some cases, marking samples had completely failed before being painted over, but in others, paint was applied over still-intact durable markings. For marking sites that were partially painted over, the evaluation criteria were applied only to durable markings that remained unpainted. In addition to rating each sample using these criteria, data were compiled on installation date, traffic volume, highway configuration, and total project quantity and length.

Table 5 summarizes 1986 field inspection results by number of contracts, samples, sites inspected, and year installed. Then, marking percentages in each category are provided for the three evaluation criteria. For reflectivity and physical condition, percentages are based on individual samples, but for delineation, they are based on site averages. Two important points are made in Table 5. First, 40 percent of thermoplastic contracts and over 10 percent of epoxy contracts had been in service for 4 or 5 years when surveyed. Second, more than half the epoxy samples and nearly a third of the thermoplastic had been painted over, and even many of the newer sites had been painted. On first examination, Table 5 does not appear to indicate good performance for either durable marking.

Table 5. Summary of 1986 pavement-marking survey results.

Year Striped	Epoxy Number of Contracts	Epoxy Sites	Epoxy Samples	Thermoplastic Number of Contracts	Thermoplastic Sites	Thermoplastic Samples
1981	1	4	12	21	84	168
1982	4	16	40	19	76	156
1983	7	28	60	20	80	160
1984	21	84	208	18	72	152
1985	16	64	176	22	88	176
Total	49	196	496	100	400	812

	Epoxy					Thermoplastic				
Year	Poor	Fair	Good	Excellent	Painted Over	Poor	Fair	Good	Excellent	Painted Over
REFLECTIVITY, PERCENT OF ALL SAMPLES										
1981	8.3	58.3	33.3	0.0	0.0	11.9	16.7	2.3	0.0	69.0
1982	0.0	10.0	0.0	0.0	90.0	15.3	47.4	2.6	0.0	34.6
1983	3.3	11.7	5.0	3.3	76.6	11.3	47.5	1.9	0.0	39.3
1984	3.8	9.1	11.1	14.4	61.5	30.3	54.6	3.9	0.0	11.2
1985	7.9	14.6	12.2	22.6	42.7	13.6	59.1	21.6	5.7	0.0
Total	4.9	12.6	10.3	14.3	57.8	16.3	45.0	6.8	1.2	30.8
PHYSICAL CONDITION, PERCENT OF ALL SAMPLES										
1981	8.3	41.7	50.0	0.0	0.0	7.1	16.7	7.1	0.0	69.0
1982	0.0	10.0	0.0	0.0	90.0	6.4	32.7	26.3	0.0	34.6
1983	6.7	13.3	3.3	0.0	76.6	4.4	16.9	38.1	1.3	39.3
1984	4.3	18.3	15.9	0.0	61.5	1.9	11.8	74.3	0.7	11.2
1985	7.9	10.9	37.8	0.6	42.7	4.5	11.9	53.4	30.1	0.0
Total	5.6	15.1	21.3	0.2	57.8	4.9	17.9	39.5	6.9	30.8

DELINEATION LEVEL, PERCENT OF ALL SITES*

	Epoxy					Thermoplastic				
Year	Failed	Poor	Fair	Good	Painted Over	Failed	Poor	Fair	Good	Painted Over
1981	0.0	0.0	100.0	0.0	0.0	3.6	7.1	13.1	9.5	66.7
1982	0.0	0.0	12.5	0.0	87.5	0.0	3.9	47.4	18.4	30.3
1983	3.6	0.0	17.9	7.1	71.4	0.0	5.0	25.0	38.8	31.3
1984	4.6	0.0	28.6	9.5	57.1	0.0	4.2	15.3	75.0	5.6
1985	6.2	12.5	12.5	43.7	25.0	0.0	7.9	20.5	71.6	0.0
Total	4.6	4.1	21.9	19.4	50.0	0.8	5.8	24.0	42.5	27.0

*Ratings based on remaining material for partially repainted sites.

Further inspection of the data, however, revealed two points that explained most of the unsatisfactory marking conditions found. Table 5 shows that more recent marking contracts, on the average, were in better condition, and fewer had been painted over than on older contracts. Examination of individual contract characteristics further shows that most of those painted over, especially those partially painted prematurely, were very short projects. Typically, they consisted of bridge rehabilitations, intersection improvements, or similar short projects that had included durable markings. These projects typically had painted markings adjoining the short length of durable markings. When

Table 6. Adjusted results of 1986 pavement-marking survey.

	% of Contracts Satisfactory*	
Rating Criteria	Epoxy	Thermoplastic
Reflectivity	88	76
Physical Condition	87	93
Daytime Delineation	91	99
Average Age, years	2	2.5
Adjusted Number of Projects**	28	75
Total Projects	49	100

*Fair or better ratings.
**Failed projects 3 or more years old and very short projects that had been painted are not considered.

painted markings were restriped each year, durable markings were often painted over as well, because they comprised only a short section of the entire route.

Repainting on short projects thus is not necessarily indicative of unsatisfactory performance. Similarly, projects providing three years of service before failure or repainting are considered to have performed satisfactorily. Table 6 was thus developed by filtering out short painted projects and failed or painted projects at least three years old. The remaining projects -- 28 for epoxy and 75 for thermoplastic -- are to be expected to remain in serviceable condition. As this summary shows, nearly all these projects are providing satisfactory service. The small number of projects painted each year and the wide range of environmental and traffic conditions experienced over this sample make it impossible to develop precise forecasts of marking service lives across the state. However, by eliminating the adverse experience with very short projects, it appears that most durable marking projects can provide at least three years of satisfactory service. Use of this service life in developing the new policy would thus be conservative.

D. Program Scope and Projected Unit Costs

Important in assessing the impact of any policy change is projection of the program size and material unit prices under the new policy. Thus, it was necessary to develop forecasts for both parameters.

Because a precise inventory of pavement marking program scope was not available, it was necessary to estimate one based on the highway inventory discussed earlier in this chapter. For four-lane divided highways, the four solid edge lines and two skip lines total 4.5 miles of marking per centerline mile of roadway. For six- and eight-lane facilities, this figure increased to 4.75 and 5.0 miles of marking per centerline mile, respectively, and ramp and intersection markings add additional striping. Total mileage for interstates, limited access, and arterials is 4,124, of which 29 percent is two-lane arterials. On two-lane roadways, the striping mileage ranges from 2.25 to 4.0 miles per centerline mile, depending on centerline configuration. Because only a small portion of state highways exceed four lanes and total ramp mileage is small --

as shown by lane-mile totals given at the beginning of this chapter -- use of 4.2 stripe-miles per centerline mile was selected as a reasonable approximation for highways in the interstate, limited-access, and arterial categories. For highways in the other category -- predominantly rural two-lane -- 3.4 stripe miles per centerline mile was considered reasonable. The resulting marking inventory using these figures is as follows:

System	Centerline Miles	Stripe Miles	Multiplier*
Interstate, Limited Access, Arterial	4,124	17,320	4.2
Other	11,381	38,695	3.4
Total	15,505	56,015	

*Stripe miles per centerline mile.

Because only a small amount of paint lines are restriped by Highway Maintenance each year on high-volume roadways, and durable markings were shown in Tables 5 and 6 to provide about three years of service, the total inventory figure closely agrees with the 1985 program in Table 1. Multiplying the durable marking quantities in that table by three years -- average service life -- and summing, the total is 58,645 stripe miles. The difference between this total program and the total inventory of 56,015 stripe miles calculated can be attributed to maintenance restriping.

The analysis in Section B of this chapter revealed that unit costs for epoxy and thermoplastic markings were considerably lower for large contracts. By eliminating small contracts and relying more heavily on special striping contracts for durable marking installation, it was estimated that some price advantages would be obtained. Thus, estimated unit costs of $0.20/ft for epoxy and $0.30 ft for thermoplastic appeared reasonable. The analysis in Table 2 and project cost experience in earlier years confirmed that these prices are achievable under favorable conditions. Table 1 shows that pavement preparation to remove deteriorated markings, surface dirt, and contamination before installing durable markings adds considerably to their cost. However, based on more favorable prices achieved on large contracts, and the acceptability of less thorough preparation when restriping epoxy markings, it appears that a unit cost of $0.10/ft could be expected under a new policy. Further, it was estimated that only about half the epoxy markings would require pavement preparation. Skip lines can be placed adjacent to existing worn markings with no preparation, and some solid lines will require no preparation when placed over existing worn epoxy lines. The resulting estimated installed cost for epoxy lines, including pavement preparation, is $0.25/ft. Because thermoplastic is normally placed on new asphalt pavement requiring no preparation its price remains at $0.30/ft.

A 1985 cost analysis by the Traffic and Safety Division produced a total installed cost for traffic paint of $0.025/ft for the Department's standard modified-alkyd traffic paint including material, labor, and equipment. Because of slightly lower paint prices and productivity improvements over the past few

years, this price has remained relatively stable. Based on prices for chlorinated-rubber paint purchased by the Department in 1982, 1984, and 1987, it appeared that installed cost of this paint would increase to about $0.035/ft. Again based on stable paint prices and productivity improvements under the new policy, this unit price was considered stable for the foreseeable future.

Table 1 also gives a unit price for a small quantity of modified-alkyd traffic paint placed under contract. The high cost is attributable to small, scattered contract quantities, and a rigid specification requiring a truck-mounted line striper. This striping was applied primarily on capital projects where poor pavement condition or planned future resurfacing precluded use of durable markings. Under the new policy, small quantities of traffic paint would continue to be needed on capital contracts where durable markings are not required, but small quantities and remote locations made it inefficient for Highway Maintenance to provide striping. Based on judgment and conversations with paint striping contractors, it appeared that a relaxed specification permitting use of portable stripers could result in a sizable price reduction. Thus, a price of $0.06/ft was estimated for contract paint striping where such stripers could be used for limited striping and a revised specification was implemented.

E. Survey of Regional Offices

Once the need for improvements in the Department's pavement-marking policy became apparent, one of the first steps was to solicit input from the regional offices. Under the previous policy, each region was responsible for its own markings. However, with inclusion of durable markings in capital contracts, Department striping crews were relieved of responsibility for installing initial striping on complete capital contracts.

Changing to an improved traffic paint and eliminating durable markings from many capital contracts would thus have a substantial effect on regional striping programs, and their input was needed before work could begin on formulating the new policy. A questionnaire was prepared and sent to each region in the spring of 1986 requesting answers to four specific questions. Nine of the ten regions responded as follows:

Question	Answer			
	Yes	Qualified Yes	No	No Response
1. Can you provide initial striping on completed projects, if durable markings are eliminated from most capital projects?	3	3	3	--
2. Can you maintain markings if durables are eliminated from most capital projects?	2	3	4	--
3. Would better traffic paint affect your responses to Questions 1 and 2?	6	1	1	1

Question	Answer: Yes	Qualified Yes	No	No Response
4. Should the Department change its policy regarding durable markings on capital projects, possibly including their elimination?	8	--	--	1

From the response to Question 4 and additional comments provided by the regions. there was obvious widespread support for changes in the pavement-marking policy. Most responded with a qualified yes or an outright no to the first two questions. The regions strongly believed that any additional workload placed on their striping crews -- either initial striping of completed projects or a reduction in durable markings -- would make it impossible to complete marking programs with current resources. However, an improvement in paint durability was almost universally considered an offsetting factor if it could be achieved.

These responses confirmed two important principles. First, Main Office dissatisfaction with current striping policy was shared by the regions. Second, regional striping resources were essentially fully committed, and any changes in the program would require either additional funds or improved efficiency, such as more durable striping materials or lower unit costs, to achieve larger total quantities of durable markings.

III. POLICY CONSIDERATIONS

A. Cost Considerations

Early in developing the revised policy, top-level Department managers acknowledged the need to improve pavement-marking performance to achieve effective year-round markings on all highways under their jurisdiction. Unfortunately, the pavement-marking program is one of many competing for the same limited resources. Thus, a basic objective set early in policy development was that it should be as cost-neutral as possible.

A small increase in maintenance funding had been approved for purchase of chlorinated-rubber traffic paint in 1987. However, other program areas -- pavement rehabilitation, bridge improvements, safety upgradings -- were also considered important, and no substantial shift of funds to pavement markings would be approved, especially under capital projects. Thus, any improvements in marking performance would have to be achieved through improved cost effectiveness rather than increased expenditure. To stripe more highways using durable markings applied under capital contracts, improvements would be necessary in unit prices or marking durability. To afford higher-priced traffic paint for the maintenance programs, the cost increase would have to be at least partially offset by reduction in the total quantity of striping installed.

B. Selection of Highways for Durable Markings

Because of the low first cost of painted markings, even considering the higher cost of chlorinated-rubber paint, durable markings cannot usually compete with painted markings in terms of cost effectiveness on highways where paint lasts for an entire year. Epoxy (with the necessary pavement preparation) initially costs about seven times as much as chlorinated-rubber paint, and thermoplastic about nine times as much. Even using a low discount rate, these materials would have to last about ten years to compete with paint from the standpoint of cost. On higher-volume roads, however, where repainting is necessary, durable materials become cost competitive in much less than five years. Where painted markings wear out in midwinter, no amount of repainting can achieve the goal of year-round markings, and only durable markings can be considered to meet that goal.

Thus, it was apparent that high-volume roadways were the best candidates for cost-effective use of durable markings. Experience with such markings reported in earlier studies, and the performance review reported here, all confirmed that durables could last three years or more on most state highways. Although the entire range of performance had not been defined for either modified-alkyd or chlorinated-rubber paints, much information was available. Years of experience have shown that the current standard modified-alkyd paint will not last an

entire year except on very low-volume roadways in the state's areas of least severe climate. However, from experience in accelerated wear tests and two pilot installations, chlorinated-rubber appeared capable of year-round service under moderate traffic. Although the upper traffic limit had not been defined, it appeared adequate for most rural two-lane highways generally carrying less than 5,000 vehicles daily, and for low-volume secondary urban routes. On interstates and other limited-access highways and on high-volume urban arterials, traffic is usually heavier and traffic patterns more complex, so chances of chlorinated-rubber lasting an entire year are less. In addition, these primary routes often carry a higher proportion of non-local drivers, increasing the need for good markings. Thus, it was decided that durable markings would be specified for interstate, other limited access, and urban arterials carrying average lane volumes over 2500 ADT. All other highways would be marked with traffic paint. Aside from some minor exceptions -- a few low-volume rural interstates and high-volume rural arterials -- these criteria would largely ensure use of durable markings where cost effective and necessary to provide year-round markings, and paint where it could provide year-round service and the lowest cost. These criteria also offer an important advantage -- ease of interpretation and implementation.

For further improvement of the cost effectiveness and efficiency of this policy, two exceptions to these criteria were necessary:

1. Along highway corridors conditions sometimes vary over short distances, requiring frequent changes in marking type over short lengths of highway. Thus, a provision was added requiring development of a plan "that considers the above criteria but adjusts to provide for reasonable continuity along corridors."

2. Although average installed cost of traffic paint is low compared to durable markings, several factors may increase it to the point that durable markings are most cost effective, even when paint can provide year-round service. For example, to stripe highways in remote areas, crews must travel long distances from their headquarters, resulting in low productivity. Overnight stays or longer working days have sometimes increased productivity, but travel expenses, subsistence allowances, and overtime pay still increased unit costs. Thus, a provision was added to the Department's policy permitting use of durables on such remote highways when economic analysis showed them to be cost effective.

C. Material Selection

The Department's standard modified-alkyd paint had a poor performance history, but accelerated wear tests previously mentioned showed that improved traffic paints were available to meet the goal of year-round markings. Thus, it became apparent early in this development effort that conversion to the improved chlorinated rubber paint would be essential. This paint would be necessary to provide a low-cost material able to last 12 months on a large portion of the highway network. Unless both properties were available in one material -- low initial cost and 12-month durability -- it would not be possible to achieve the primary goal without a major cost increase. In addition to an improved traffic

paint, it was also necessary to select the most cost-effective durable marking materials for situations where traffic paint was not appropriate. The Department had considerable experience with epoxy, thermoplastic, and preformed tape, but less with polyester. To ensure reliability in the resulting policy, it was decided to exclude polyester as a material choice at this time, even though it offers some cost advantages. Instead, its trial use will continue under close scrutiny, until it can be added to the material selection after sufficient experience in its use has been gained.

Thermoplastic markings have generally provided good performance, especially on new asphalt-concrete pavements. Although initially more expensive than epoxy, service life has been longer, resulting in equivalent annual costs. Because of their thicker profile, thermoplastics offer improved wet-night visibility compared to lower-profile markings. However, this thickness increases susceptibility to snowplow damage. Although an excellent bond is normally achieved on new asphalt concrete, performance on existing asphalt concrete (AC) has varied, sometimes with extensive bond failure. Thermoplastic performance on portland-cement-concrete (PCC) pavement has been highly inconsistent. Thus, use of thermoplastic markings was limited to new asphalt pavements.

Epoxy markings have also provided good performance on both AC and PC surfaces. Thus, epoxy was the material selected for existing AC and all PC pavements. With the exception of excellent performance of thermoplastic on new AC pavements, past performance and cost experience indicated that epoxy -- of the durables now in widespread use in New York -- provides the lowest annual cost for longitudinal striping.

Under the previous policy, preformed tape was permitted for intersection markings -- crosswalks, stop bars, legends, and turn lanes -- and for limited use as longitudinal lines on high-volume lighted roadways. The high cost -- $1.50/ft average installed cost -- and relatively low long-term reflectivity make this material less suited for longitudinal markings, even though its durability is superior to other materials. Special intersection markings receive the most severe wear, but do not require as high a level of reflectivity as longitudinal markings. In addition, their installation is labor intensive, reducing the effect of material cost and narrowing the gap in installed cost between tape and other durable markings. Thus, preformed tape is considered cost effective for these special markings, and was selected as the standard marking material for such locations under the new policy.

Limited use of tape for longitudinal markings under the previous policy was based on inability to maintain painted markings at these high-volume locations after initial durable markings wore out. The increased life and easier replacement of tape for small-quantity applications ensures continuous markings, especially on lighted highways where reflectivity is less critical. However, under the new policy, improved distribution and restriping of all durable markings would achieve the same purpose without higher-priced tape markings. Thus, this special use of tape for longitudinal lines was considered unnecessary under the new policy.

Cross-hatch markings at intersection gores and medians are meant to exclude traffic, and thus receive less wear than other special markings. In addition,

these markings include much larger total quantities. Thus, cross-hatch markings were grouped with other longitudinal markings in the new policy.

D. Initial Striping on Capital Contracts

With removal of durable markings from most capital contracts, a means was needed to provide initial markings at the completion of paving or other contract work. On qualifying contracts with marking quantities exceeding 100,000 lin ft, durable markings would be retained. However, for all other capital projects, initial striping would have to be arranged by other means. Two techniques were available: 1) paint striping included in the capital contract, or 2) paint striping by Maintenance forces.

Unfortunately, each had disadvantages. Current Department specifications permit a time span of 28 days to complete final markings after completion of paving at most sites, but only 7 days is permitted on roadways with more complex traffic patterns and closely spaced intersections. Any efforts to install initial striping on capital contracts would create some inefficiencies in the Maintenance striping program, which would be greatest for projects requiring 7-day completion. On the other hand, contract striping had been very expensive, and the cost would increase with contract marking quantity. Thus, both techniques offered disadvantages in terms of efficiency or cost, but the main disadvantages of the two did not overlap. It thus appeared that some compromise might minimize the negative impact of initial striping on capital projects. Several options were thus developed to examine their impact on cost and program efficiency. These are presented and discussed later in this chapter.

E. Program Management

An obvious deficiency of the previous policy was lack of clearly defined responsibility within the Department for the overall pavement-marking program. This resulted in a lack of effective coordination between the various program managers at both the Main Office and regional levels. Program areas involved in pavement marking to one degree or another included Planning and Programming, Traffic and Safety, Highway Maintenance, Equipment Management, Facilities Design, Construction, and Technical Services.

It was recognized early in developing the new policy that one program manager at the Main Office and the corresponding regional program managers must assume overall responsibility for the program. This would ensure high operational efficiency and statewide consistency in applying the policy. Although overall responsibility rests with one program manager, others are involved to various degrees in implementing and carrying out the plan. Thus, the policy would also have to spell out specific responsibilities of every involved manager, and specify necessary elements of coordination among program areas. Specific elements of program management are provided in Chapter IV.

F. Development and Assessment of Options

Based on the impacts and considerations already discussed, an initial policy was drafted presenting an overall plan for the Department's pavement-marking program. Circulated for review at both the Main Office and regional levels, it was discussed at various meetings. A number of comments were received, and after review and discussion each was either incorporated into the policy or dismissed, as appropriate. However, one major issue arose making it necessary to generate and analyze various options before a final policy acceptable to all parties was developed.

This issue was initial striping of completed capital projects. Trade-offs involved increased capital expenditures to apply painted lines by contract, versus decreased efficiency in the Maintenance striping program if state forces applied initial markings. Some of the options considered also impacted on the program's ability to provide effective year-round markings on all state-maintained highways. In all, five options were developed and assessed, along with the current policy. In addition to Options 1, 2, and 3, the final two options were termed 1-1/4 and 1-1/2 because they represented various degrees of compromise between Options 1 and 2.

Main features of the various options considered were as follows:

Option 0 (Current Policy)

- Durable markings are included on most capital projects.
- Limited striping contracts are used to apply durable markings on some existing highways.
- Highway Maintenance has responsibility for maintaining markings on existing highways using modified-alkyd traffic paint.
- Traffic paint is occasionally included in capital contracts where durable markings are not warranted.
- Highway Maintenance has no responsibility for initial striping on capital projects.

Option 1

- Capital funds remain fixed at current levels.
- Durable markings are included in qualifying capital projects meeting system and quantity criteria (>100,000 lin ft -- expressway or arterial).
- Striping contracts employing capital funds will be used to install durable markings on all other qualifying highways.
- Highway Maintenance applies initial markings on non-qualifying capital projects using traffic paint.

- No painted markings will be applied by contract.
- Highway Maintenance has responsibility for maintaining markings on existing non-qualifying roadways using chlorinated-rubber traffic paint.

Option 2

- Capital funds remain fixed at current levels.
- Durable markings are included in qualifying capital projects meeting system and quantity criteria (>100,000 lin ft -- expressway or arterial).
- Contract applied traffic paint is included in all remaining capital projects not including durable markings.
- Striping contracts employing capital funds will be used to install durable markings on qualifying highways to the extent of current funding levels.
- Highway Maintenance has no responsibility for initial striping on capital projects.
- Highway Maintenance has responsibility for maintaining markings on existing non-qualifying roadways using chlorinated-rubber traffic paint.
- Highway Maintenance has responsibility for applying painted markings on any remaining highways qualifying for durable markings, but for which capital funds are not available.

Option 3

- Capital funds are open-ended to meet program requirements.
- Durable markings are included in qualifying capital projects meeting system and quantity criteria (>100,000 lin ft -- expressway or arterial).
- Contract-applied traffic paint is included in all remaining capital projects not including durable markings.
- Striping contracts employing capital funds will be used to install durable markings on all other qualifying highways.
- Highway Maintenance has no responsibility for initial striping on capital projects.
- Highway Maintenance has responsibility for maintaining markings on existing non-qualifying roadways using chlorinated-rubber traffic paint.

Option 1-1/4

- Capital funds remain fixed at current levels.
- Durable markings are included in qualifying capital projects meeting system and quantity criteria (>100,000 lin ft -- expressway or arterial).
- Paint is applied as initial markings on non-qualifying contracts, by capital contract on small and 7-day projects, and by Highway Maintenance on large and 28-day projects.
- Striping contracts using capital funds will be used to install durable markings on qualifying highways to the extend of current funding levels.
- Highway Maintenance has responsibility for maintaining markings on existing non-qualifying roadways using chlorinated-rubber traffic paint.
- Highway Maintenance has responsibility for applying painted markings on any remaining highways qualifying for durable markings, but for which capital funds are not available.

Option 1-1/2

- Capital funds are open-ended to meet program requirements.
- Durable markings are included in qualifying capital projects meeting system and quantity criteria (>100,000 lin ft -- expressway or arterial).
- Striping contracts employing capital funds will be used to install durable markings on all other qualifying highways.
- Paint is applied as initial markings on non-qualifying contracts, by capital contract on small and 7-day projects, and by Highway Maintenance on large and 28-day projects.
- Highway Maintenance has responsibility for maintaining markings on existing non-qualifying roadways using chlorinated-rubber traffic paint.

Once the implications of each option were delineated, Table 7 was generated to compare the various options using the input parameters discussed earlier. Compared to the 1985 pavement marking program, the following are the major implications of each of the five new options:

Option 1

- The total cost is only 4 percent higher than under the previous policy.

Table 7. Comparison of pavement-marking policy options.

Policy Option	1985 Program	Option 1	Option 2	Option 3	Option 1-1/4	Option 1-1/2
Annual Mileage Placed						
Paint by Maintenance	48,620	38,695	43,345	35,252	38,643	37,834
Durables by Contract	3,260	5,196	2,768	5,196	4,953	5,196
Paint by Contract	245	--	3,443	3,443	861	861
Mileage in Service						
Paint by Maintenance	45,990	38,695	43,345	35,252	38,643	37,834
Durables by Contract	9,780	17,320	9,227	17,320	16,511	17,320
Paint by Contract	245	--	3,443	3,443	861	861
Total	56,015	56,015	56,015	56,015	56,015	56,015
Annual Cost, $M						
Paint by Maintenance	6.5	7.2	8.0	6.5	7.1	7.0
Durables by Contract	7.0	7.1	3.8	7.1	6.8	7.1
Paint by Contract	0.2	--	3.3	3.3	0.3	0.3
Total	13.7	14.3	15.1	16.9	14.2	14.4
Percent of Total Miles in Service						
Paint by Maintenance	82.1	69.1	77.4	62.9	69.0	67.5
Durables by Contract	17.5	30.9	16.5	30.9	29.5	30.9
Paint by Contract	0.4	--	6.1	6.1	1.5	1.5
Annual Mileage on Capital Contracts						
Paint by Maintenance	--	3,443	--	--	2,582	2,582
Durables by Contract	3,260	1,038	1,038	1,038	1,038	1,038
Paint by Contract	245	--	3,443	3,443	861	861
Total	3,501	4,481	4,481	4,481	4,481	4,481

- Mileage of the Highway Maintenance paint program is reduced by 20 percent.
- Highway Maintenance would be required to place initial markings on about 20 capital projects per region each year, with half scheduled in the fall.
- Durable markings would be placed on all interstates, expressways, and high-volume urban arterials -- 31 percent of the entire system.
- Capital funds for markings are fixed at current levels.
- Maintenance material costs for traffic paint increases by $0.7 million.

Option 2

- This option has the highest maintenance paint program cost and mileage of any option under the new policy.
- Maintenance paint program miles are 11 percent below current, but 12 percent above Option 1.

- Maintenance paint program cost increases 23 percent.
- All initial capital project striping is by contract, and none by Maintenance.
- Capital funds are adequate for durable markings on all interstates, 86 percent of other expressways.
- No durable markings will be placed on high-volume urban arterials, resulting in some unmarked highways by spring.
- Capital costs are fixed at current levels, but fewer durable markings are placed than under the current policy -- only 16.5 percent of the system.

Option 3

- This option has the highest total cost of all considered, an increase of $3.2 million or 23 percent above current funding.
- Mileage is down 27 percent for the Maintenance paint program.
- The Maintenance paint program is cost-neutral.
- Capital costs for contract markings are up 48 percent.
- Durable markings would be placed on all interstates, expressways, and high-volume urban arterials -- 31 percent of the entire system.
- Highway Maintenance has no responsibility for initial striping on capital projects.

Option 1-1/4

- This is the lowest-cost option other than the current policy.
- Mileage is down over 20 percent for the Maintenance paint program.
- Highway Maintenance would be responsible for about 2600 miles of initial striping on capital projects.
- Capital marking costs remain fixed at current levels.
- Durable markings would be placed on all interstates and expressways and most urban arterials -- 29.5 percent of the total system.
- Maintenance paint program costs are increased by $0.6 million for the purchase of improved paint.

Option 1-1/2

- The total cost of this option only slightly exceeds Options 1 and

1-1/4 (the lowest-cost options) and is only 5 percent higher than the current option.

- Mileage is down 22 percent for the Maintenance paint program.
- Highway Maintenance would be responsible for about 2600 miles of initial striping on capital projects.
- Durable markings would be placed on all interstates, expressways, and high-volume urban arterials -- 31 percent of the total system.
- Capital marking costs increase by $0.2 million over current levels.
- Maintenance costs increase by $0.5 million for the purchase of improved paint.

Several reiterations were involved in developing and assessing the five options and making a final choice. Option 1 was the first considered under the new policy, and its assessment showed several improvements over the current program. However, its primary drawback was complete elimination of painted markings from capital contracts, requiring Highway Maintenance to install initial markings on most capital projects. Because this included numerous small and scattered projects, as well as a tight schedule in the fall, this option was considered to present too negative an impact on the Maintenance striping program.

Under Option 2, part of the capital marking funds would be used to apply initial painted markings on projects not qualifying for durable markings. Although this would relieve Highway Maintenance of the burden of initial striping, contract paint markings using truck-mounted stripers are nearly as expensive as durable markings. Thus, total funds available for durable markings were greatly reduced. Not only would it be impossible to stripe some qualifying highways with durables to achieve year-round marking, but the required Maintenance program would be only slightly reduced in mileage from the current one. With the change to chlorinated-rubber paint, its cost would increase by 23 percent. Consequently, this option was not a viable choice.

Under Option 3, capital funds would be increased to provide initial paint striping on non-qualifying capital contracts. This would provide the lowest mileage and cost for the Maintenance paint program, and provide durables on all highways where needed. However, it increased capital costs by 48 percent, and was thus considered unacceptable.

Because none of the first three options were totally acceptable, it became necessary to compromise on the issue of initial striping on non-qualifying capital projects. The compromise was to assign Highway Maintenance responsibility for initial striping on larger capital contracts where the 28-day time requirement applied. For contracts with less than 10,000 lin ft of markings, or with a 7-day time requirement, paint striping would be included in the contract. However, to reduce striping costs, a new specification would be developed permitting portable stripers. Two options were developed under this compromise. Option 1-1/4 (capital funds fixed at current levels) resulted in a small

shortfall to complete all the desired durable markings. Option 1-1/2 (capital funds increased by 3 percent) provided adequate funds for initial paint striping on some contracts and to complete all the desired durable markings. Because these two options relieved much of the burden of painting small projects on a tight time schedule, Highway Maintenance considered them acceptable. Option 1-1/2 was selected as better because it results in durable markings on all highways where they are considered necessary, with only a nominal increase in capital funds. Under this option, it appeared that the goal of providing year-round markings on all state highways can be met. Equally important, the total cost increase is only 5 percent over current levels, meeting the objective that the new policy be as close to cost-neutral as possible.

IV. POLICY OVERVIEW

After analysis and review of the options detailed here, the revised policy was drafted in final form for distribution throughout the Department. The policy statement defines the Department's pavement-marking program objective, and provides steps to its implementation. Actual details of the policy are listed, and organizational responsibilities are spelled out. Major elements of the policy are as follows:

1. Current resources and capabilities of the Highway Maintenance striping program are to be maintained.

2. The program will continue to use a combination of traffic paint and durable materials for striping state highways. Material types are specified in the policy as discussed earlier in this report.

3. Durable marking materials will be installed and maintained by contract on limited-access highways and high-volume urban arterials (over 2500 lane ADT), and on remote highways when shown to be operationally cost effective.

4. Traffic paint will be installed and maintained by Highway Maintenance on roads carrying less traffic.

5. Durable longitudinal markings will be included as part of capital projects on qualifying highways when the marking quantity exceeds 100,000 lin ft. However, they will no longer be included for smaller quantities, or on non-qualifying highways.

6. Initial paint striping on contracts not including durable markings will be installed by a combination of Highway Maintenance and contractor forces, depending on the quantity of striping and allowable time until its completion.

7. Special markings will continue to be included in most capital projects.

8. Annual region-wide durable pavement-marking contracts will be let to stripe or restripe qualifying highways.

9. The program will continue to include a combination of Maintenance and capital funds, approximately at current levels.

10. Responsibility for overall coordination of the program is assigned to the Traffic and Safety Division. Responsibilities of other program managers are also specified in the policy.

11. Efforts will continue to improve marking technology.

12. Each region is required to develop a regional pavement-marking plan, incorporating the criteria provided in the policy. This plan will identify the highways to be striped and restriped by contract-applied durable markings, and by paint applied by Highway Maintenance.

13. Each region is required to prepare an annual regional marking program detailing proposed contract and Maintenance marking activities for the coming year.

14. Although the policy is in keeping with the purpose of providing a systematic pavement-marking program, it recognizes that flexibility is required to handle operational needs and changes in technology and funding.

REFERENCES

1. Bryden, J. E., and Gurney, G. F. Pavement Marking Materials: New York's Experience. Research Report 112, Engineering Research and Development Bureau, New York Department of Transportation, April 1984.

2. "Pavement Marking Materials and Surface Texture and Color Contrast." Engineering Instruction 79-34, New York State Department of Transportation, June 16, 1979.

3. "Pavement Marking Materials for Capital Projects." Engineering Instruction 83-26, New York State Department of Transportation May 17, 1973.

4. Bryden, J. E., and Lorini, R. A. Traffic Paint Performance in Accelerated Wear Tests. Research Report 137, Engineering Research and Development Bureau, New York State Department of Transportation, May 1987.

5. Bryden, J. E.; Lorini, R. A.; and Kelly, P. D. Reflectivity and Durability of Epoxy Pavement Markings. Research Report 127, Engineering Research and Development Bureau, New York State Department of Transportation, October 1985.

6. Bryden, J. E., and Lorini, R. A. Test Installation of Chlorinated-Rubber Traffic Paint. Research Report 125, Engineering Research and Development Bureau, New York State Department of Transportation, August 1985.

7. Bryden, J.E., and Gurney, G. F. Performance of Thermoplastic Pavement Markings. Research Report 120, Engineering Research and Development Bureau, New York State Department of Transportation, April 1985.

8. Bryden, J. E., and Gurney, G. F. Evaluation of Long-Life Pavement Markings. Research Report 114, Engineering Research and Development Bureau, New York State Department of Transportation, June 1984.

9. Bryden, J. E.; Lorini, R. A.; and Gurney, G. F. Performance of Preformed Pavement Marking Tapes. Research Report 104, Engineering Research and Development Bureau, New York State Department of Transportation, November 1983.

10. Bryden, J. E., and Lorini, R. A. Experimental Pavement Delineation Treatments. Research Report 87, Engineering Research and Development Bureau, New York State Department of Transportation, June 1981.

11. Bryden, J. E. Performance of Shoulder and Median Contrast Treatments. Research Report 71, Engineering Research and Development Bureau, New York State Department of Transportation, May 1979.

12. Pavement Marking Policy. Technical Services Division, New York State Department of Transportation, June 5, 1987.

Other Publications in Print Concerning Traffic and Safety

The following research reports (RR) and special reports (SR) are listed in reverse chronology -- newest first, oldest last -- by month of publication, and are available without charge to interested readers who write ordering by number to the Engineering Research and Development Bureau, New York State Department of Transportation, State Campus, Albany NY 12232, or call (518) 457-5826.

TRAFFIC PAINT PERFORMANCE IN ACCELERATED WEAR TESTS, RR 137, 4/87.
METHODS FOR REMOVAL OF PAVEMENT MARKINGS, RR 130, 5/86.
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